ADDENDUM NO. 2

TO: ALL BIDDERS OF RECORD

PROJECT: Hell Creek State Park Infrastructure Upgrades

FWP PROJECT #: 7116507
DATE: April 3rd, 2018

FROM: Darcy Yakoweshen, Montana FWP Project Manager

Acknowledge receipt of this addendum by inserting its number and date in the Proposal Form and on the Bid Envelope. Failure to do so may subject bidder to disqualification.

This Addendum forms a part of the Contract Documents. Clarification and/or modifications area as follows:

1. **Sheet 13 of the Drawings:** Delete note 11 under the Piping Key and replace with the following.

   11 ULTRASONIC FLOW METER PER SECTION 02615.2.4.A

2. **Geotechnical Report**: At the request of the potential Bidders, the geotechnical report for the project has been made available and is attached.

3. **Pre-Bid Date Rescheduled**: The pre-bid date has been re-scheduled from April 3rd to the new date of **April 10th, 2018 at 11:00am.** We will meet next to the Hell Creek State Park Playground.

END OF ADDENDUM NO. 2

GEOTECHNICAL EVALUATION REPORT

Proposed Water and Wastewater
Treatment System Improvements
Hell Creek State Park
North of Jordan, Montana
Project 17-3585G

Submitted by

SK GEOTECHNICAL

2511 Holman Avenue
P. O. Box 80190
Billings, Montana 59108-0910

Prepared for

Great West Engineering, Inc.
2501 Belt View Drive
Helena, Montana 59601

September 19, 2017

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September 19, 2017

Project 17-3585G
GWE Project 1-17113

Mr. Todd Kuxhaus
Great West Engineering, Inc.
2501 Belt View Drive
Helena, Montana 59601
Via Email: tkuxhaus@greatwesteng.com

Dear Mr. Kuxhaus:

Re: Geotechnical Evaluation, Proposed Water and Wastewater Treatment System Improvements, Hell Creek State Park, North of Jordan, Montana

We have completed the geotechnical evaluation authorized by our Subconsultant Agreement dated August 7, 2017. The purpose of the geotechnical evaluation was to evaluate subsurface soil and groundwater conditions at the boring locations for the project, and to assist you in preparing plans and specifications.

Summary of Results

A total of four soil borings were completed for the project: Boring ST-1 for the buried 20,000-gallon water tank, Boring ST-2 for the pump building, Boring ST-3 for the grease interceptor and pump station, and Boring ST-4 for the drainfield area dose and recirculation tanks. Borings ST-1 and ST-2 encountered a similar profile consisting of 0.5 to 0.7 foot of organic clay topsoil underlain by slopewash lean clay to a depth ranging from 4 1/2 to 6 1/2 feet over decomposed claystone, claystone, and shale bedrock. Boring ST-3 encountered 0.8 foot of organic clay topsoil underlain by rather soft to medium consistent fat clay and lean to fat clay decomposed claystone, which was found to be primarily wet and saturated, most likely due to the proximity to the existing fish cleaning station. Perched groundwater appears to have been present in this boring at a depth of about 6 feet. Boring ST-4 encountered 0.6 foot of organic clay topsoil underlain by decomposed claystone and decomposed sandstone to a depth of 11 feet where weathered claystone and claystone bedrock were encountered.

Laboratory tests indicated the slopewash deposits encountered in Borings ST-1 and ST-2 were highly collapsible, i.e., will consolidate if they get wet, causing settlement. Laboratory swell and classification tests indicated the decomposed claystone, claystone, and shale bedrock primarily consisted of lean clay and lean to fat clay that was high to very high plasticity. In our opinion, these clays and bedrock are moderately to highly expansive.

Summary of Analysis and Recommendations

As can be seen on the attached Geologic Sketch, the entire shoreline of Fort Peck Lake in the Hell Creek State Park area is mapped as "landslide deposits." Active landslides can readily be seen in the residential area upslope and north of the marina. These landslides have caused distress to several of the buildings. Although a geotechnical reconnaissance was not part of our scope of services, we are not aware of any active landslides in the proposed improvement areas. Even so, it is critical all members of the ownership, design, construction, and development team recognize there is a risk the project could activate landslides.

Landslides can cause significant damage and are very difficult and expensive to stabilize once movement occurs.

Based on the results of the borings and laboratory tests, it is our opinion highly expansive soils and bedrock are present in the entire area. If the proposed structures are placed directly on these soils and bedrock, and especially if there is leakage, we anticipate several inches of heave could occur, causing significant distress to the structures as well as pipelines connected to them. We therefore recommend performing a partial subexcavation beneath the proposed 20,000-gallon water tank, dose tank, recirculation tank, and any other buried tanks not in the vicinity of the existing fish cleaning station. These soils and bedrock should then be replaced with non-expansive clay backfill, which most likely will have to be imported. For the pump building, we recommend supporting the building on a frost-depth spread footing and stem wall. The partial subexcavation and replacement with non-expansive clay backfill should also be performed beneath this building's frost-depth footings.

Boring ST-3 performed for the new grease interceptor and E-One pump station indicated these clays were wet and saturated. The source of the water saturating these clays is unknown, but is most likely associated with the fish cleaning station or swale located in the area. Because these clays are already wet and saturated, we do not anticipate they can absorb moisture and swell, and structures can be placed directly on the wet clays. However, they will need to be designed for higher lateral earth pressures and buoyancy associated with possible perched groundwater at a depth of only 6 feet. Dewatering could also be necessary.

General

Please refer to the attached report for more detailed results of our fieldwork, engineering analyses and recommendations.

Thank you for using SK Geotechnical. If you have any questions regarding this report, or require our services during the construction phase of this project, please contact us at your convenience.

Sincerely,

Gregory T. Staffileno, PE
Principal, Geotechnical Engineer

Brett M. Warren, PE
Reviewing Engineer

Attachment:
Geotechnical Evaluation Report

Table of Contents

Description **Page**

Table of Contents (continued)

A. Introduction

A.1. Project

Montana Fish, Wildlife & Parks is planning improvements to the water and wastewater facilities at Hell Creek State Park north of Jordan, Montana. The site is located along the west shore of Hell Creek Bay on Fort Peck Lake. Great West Engineering, Inc., is the civil engineering firm providing consulting, design, surveying, and other professional services for the project.

A.2. Purpose of this Evaluation

The purpose of the geotechnical evaluation was to characterize and evaluate subsurface soil and groundwater conditions at the selected boring locations for the project.

A.3. Scope

Our scope of services was submitted in a proposal to Great West dated December 22, 2016. On August 7, 2017, Great West executed a Subconsultant Agreement for Professional Services for our geotechnical work.

Our scope of services was limited to:

- Having our drill crew stake the boring locations,
- Coordinating the locating of underground utilities near the boring locations,
- Conducting four penetration test borings at various locations for the water and wastewater treatment improvements,
- Collecting some thin-walled tube and bulk bag samples from the borings while drilling,
- Classifying the samples and preparing boring logs,
- Returning the samples to our laboratory for visual classification and logging by a geotechnical engineer,
- Conducting the following laboratory tests on samples from the borings:
    - Moisture content tests on penetration test samples,
    - Three classification tests (Atterberg limits and sieve analysis),
    - Two consolidation/swell tests,
    - Two corrosion tests,
    - One standard Proctor test,

- Analyzing the results of the field and laboratory tests and formulating recommendations for earthwork, spread footing foundations and buried tanks,
- Discussing the project with Mr. Todd Kuxhaus of Great West, and
- Submitting a geotechnical evaluation report containing logs of the borings, our analysis of the field and laboratory tests, and recommendations for earthwork, spread footing foundations, and buried tanks.

We wish to point out that our scope of services did not include a geotechnical engineering reconnaissance of the site. Also, slope stability analysis and more detailed laboratory triaxial shear testing to evaluate slide stabilization was not performed, nor included in our scope of services. Also, our services did not include percolation testing for the drainfield area. These services can be provided, if desired, but an additional proposal for these services would need to be submitted.

A.4. Documents Provided

Great West provided us with numerous documents for preparation of our proposal and geotechnical report for the project. Most recently, Great West provided us with 20 plan sheets of the proposed improvements dated August 11, 2017. Sheets 4, 7, and 8 were used for our Boring Location Sketches in the Appendix of this report.

A.5. Locations and Elevations

Boring locations were selected by our personnel based on the most current drawings of the proposed improvements available prior to the drilling. The locations are shown on the Boring Location Sketches in the Appendix. The locations were referenced to existing fixed features, such as fences and transformers, located near each area. Penetration test borings are designated by the prefix "ST."

Ground surface elevations at the borings were interpolated from the contour lines on the provided sheets. These contour lines are shown on each of the Boring Location Sketches, as well. The interval between the contour lines was 1 foot, thus the accuracy of the elevations should be considered plus or minus 1/2 foot for this report.

B. Results

B.1. Logs

Log of Boring sheets indicating the depths and identifications of the various soil strata, the penetration resistances, laboratory test data and water level information are attached. It should be noted the depths shown as boundaries between the strata are only approximate. The actual changes may be transitions and the depths of the changes vary between borings.

Geologic origins presented for each stratum on the Log of Boring sheets are based on the soil types, blows per foot, and available common knowledge of the depositional history of the site. Because of the complex glacial and post-glacial depositional environments, geologic origins are frequently difficult to ascertain. A detailed evaluation of the geologic history of the site was not performed.

B.2. Site and Geologic Conditions

A portion of the geologic map for the area is included on the Geologic Sketch in the Appendix. As the Geologic Sketch indicates, the entire area along Fort Peck Lake in the vicinity of the proposed improvements is mapped as "landslide deposits." Even though the proposed improvements have been located in low-lying areas with flatter slopes to minimize the concerns related to landslides, the Geologic Sketch shows that landslide deposits are present in the area, but may have been eroded to be less distinguishable.

We are aware of several active, fairly major landslides occurring northwest of the marina building in the residential area. These active landslides move several inches or more a year, causing significant distress to several of the existing buildings. Some of the buildings have adjustable column systems so they can be releveled each year as movement occurs. Other landslides can also be readily seen when standing at the marina and looking east across Hell Creek Bay at the hillside. These landslides, several hundred feet wide and long, can be seen extending into the lake.

In the vicinity of the proposed water storage tank and pump building, the ground surface is sloping downward towards the southwest at a slope ranging from about 10 to 15 percent. In the vicinity of the grease interceptor and pump station near the existing fish cleaning station, the ground surface is relatively level with a gentle slope downward towards the south of about 1 to 2 percent. We wish to point out, this area does have an existing swale in the vicinity of the proposed improvements. This swale appears to be about 2 to 3 feet deep, as seen on the Boring Location Sketch. In the vicinity of the recirculation tank and drainfield area, the ground surface is sloping downward towards the east, northeast at a slope ranging from about 6 to 9 percent. At the time of our fieldwork, these areas of the site were covered with fairly lush native grasses.

B.3. Soils

Organic clay topsoil was encountered in the four borings to depths ranging from 0.5 to 0.8 foot. Beneath the topsoil, the general soil profile encountered at the borings was slopewash, decomposed claystone, and decomposed sandstone underlain by claystone and shale bedrock. These strata in each of the areas and borings are discussed in more detail below.

B.3.a. Water Tank and Pump Building Area. Borings ST-1 and ST-2 were performed in the water tank and pump building areas as indicated on the Boring Location Sketch (Sheet 4) in the Appendix.

These borings encountered 0.5 and 0.7 foot of organic clay topsoil, respectively. Boring ST-1 in the water tank area then encountered slopewash to a depth of 6 1/2 feet, underlain by decomposed claystone to 8 1/2 feet, where claystone was encountered to a depth of 11 feet. This boring then encountered shale bedrock to its termination depth of 20 feet. Boring ST-2 in the pump building encountered similar slopewash to a depth of 4 1/2 feet underlain by shale bedrock to its termination depth of 20 feet.

Penetration resistances in the silty clay and lean clay slopewash generally ranged from 5 to 8 blows per foot (BPF), indicating these clays were rather soft to medium. The penetration resistance in the sandy lean clay decomposed claystone was 7 BPF, indicating it was medium consistent. Penetration resistances in the claystone and shale bedrock ranged from 15 to 29 BPF, indicating it was stiff to very stiff by soil consistency standards, but considered very soft bedrock hardness. We wish to point out, the shale did contain slickensides (glassy shear surfaces within the samples), which are an indication of landslides. Groundwater was not encountered in the borings to their termination depths.

B.3.b. Grease Interceptor and Pump Station Area. Boring ST-3 was performed in the grease interceptor and pump station area as indicated on the Boring Location Sketch (Sheet 7) in the Appendix. As previously indicated, this boring was located adjacent to the existing fish cleaning station and near an existing swale sandwiched between the fish cleaning station and Hell Creek Road.

Boring ST-3 encountered 0.8 foot of organic clay topsoil underlain by fat clay and lean to fat clay decomposed claystone to the boring's termination depth of 20 feet. Penetration resistances in the clays ranged from 4 to 8 BPF. Pocket penetrometer strengths ranged from about 2 1/4 to only 1/2 tons per square foot (tsf), and generally decreased with depth as the clays became wetter. These values indicated the fat clay and lean to fat clay were medium to rather soft.

We wish to also point out, these clays were wet, and well over the clays' optimum moisture content. Moisture contents in the clays ranged from about 21.6 to 31.7 percent. Possible perched groundwater was encountered at a depth of about 6 feet. Static groundwater was encountered in the boring at a depth of 19 1/2 feet.

It is unknown what is actually causing the saturation of the existing lean to fat clay and fat clay soils in this area. Existing tanks used for the fish cleaning station or water lines servicing the area could be leaking. Outlets to the existing drainfield could also be leaking. The existing drainage swale could also be collecting snowfall and surface water runoff, further saturating these clays.

B.3.c. Drainfield and Recirculation Tank Area. Boring ST-4 was performed in the drainfield and recirculation tank area as indicated on the attached Boring Location Sketch (Sheet 8) in the Appendix. This boring encountered 0.6 foot of organic clay underlain by decomposed claystone consisting of lean clay to 1 1/2 feet over decomposed sandstone consisting of silty sand to 6 feet. Decomposed claystone consisting of lean clay and sandy lean clay was then encountered to a depth of 11 feet. Below 11 feet, weathered claystone consisting of fat clay was encountered to 13 1/2 feet where claystone bedrock was then encountered to the boring's termination depth.

Penetration resistances in the decomposed claystone to a depth of 11 feet ranged from 8 to 16 BPF, indicating the clays were medium to stiff. The penetration resistance in the decomposed sandstone was 11 BPF, indicating it was medium dense. Penetration resistances in the weathered claystone and claystone ranged from 16 to 30 BPF, indicating it was stiff to hard by soil consistency standards, but considered very soft bedrock hardness. Groundwater was not encountered in the boring to its termination depth.

B.4. Groundwater Observations

As previously indicated, Boring ST-3, performed near the existing fish cleaning station, encountered wet, saturated clays below a depth of 1 1/2 feet. The reason these clays are wet and saturated is unknown, but it could be due to leakage from existing water and wastewater pipelines, storage tanks, or nearby swale.

Static groundwater was encountered in Boring ST-3 at a depth of 19 1/2 feet while drilling. Possible perched groundwater was encountered at a depth of 6 feet while drilling, which corresponds to an elevation of about 2260 on the site datum. We wish to point out, several days or longer is typically necessary to obtain a stable groundwater measurement in these types of clay soils and bedrock.

B.5. Laboratory Tests

Laboratory tests were performed on various samples for moisture content, classification, consolidation/swell, corrosion, and one Proctor. The results of these tests are attached to this report in the Appendix and briefly discussed below.

B.5.a. Moisture Contents. Moisture content tests were performed on all of the penetration test samples from the four borings to their termination depth of 20 feet. The results are presented on the attached boring logs. In summary, the moisture contents in Borings ST-1, ST-2, and ST-4 indicated the soils, decomposed bedrock, and bedrock were rather dry to moist in these areas. In Boring ST-3, the moisture contents indicated the clays below a depth of 1 1/2 feet were wet, saturated.

B.5.b. Classification and Proctor Tests. The results of the classification (Atterberg limits and sieve analysis) and standard Proctor (ASTM D 698) tests are summarized in Table 1 below. As can be seen, one sample classified as fat clay while the other two samples classified as lean clay. We wish to point out, however, the plasticity indexes of all of the samples ranged from 30 to 50, which are high to very high values.

Table 1. Summary of Classification and Proctor Tests

Boring	Depth (feet)	Atterberg Limits			P_{200} (%)	ASTM Symbol	Proctor	
		LL	PL	PI			MDD (pcf)	OMC (%)
ST-1	13 to 14	72	22	50	98	CH	---	---
ST-2	1 to 5	48	17	31	93	CL	104.0	19.4
ST-2	3 to 4	44	14	30	95	CL	---	---

B.5.c. Corrosion Tests. The results of the corrosion tests are indicated in Table 2 below.

Table 2. Summary of Corrosion Test Results

Boring	Depth (feet)	Resistivity (ohm-cm)	pH	Marble pH	Sulfate (wt %)
ST-1	13 to 14	188	7.15	7.71	2.39
ST-2	3 to 4	309	7.44	7.56	0.23

B.5.d. Consolidation Test. The results of the consolidation test performed on the slopewash sample from Boring ST-2 from 3 to 4 feet is shown on the graph in the Appendix. The sample collapsed about 5 percent when inundated under a load of 1,000 pounds per square foot (psf). This is a very high value and consistent with unconsolidated slopewash deposits. Compression under a load increase of 1,500 psf was about 7 percent, which is also a very high value.

B.5.e. Swell Test. The results of the swell test performed on the shale sample from Boring ST-1 from 13 to 14 feet are shown on the graph in the Appendix. The sample swelled about 2 percent when it was inundated under a load of about 500 psf. This is a moderate to high value. The swell pressure was about 2,500 psf, which is a moderate to high value, as well.

C. 20,000-Gallon Water Tank Analyses and Recommendations

C.1. Proposed Construction

We were provided with details showing the proposed water tank. The tank has a diameter of approximately 10 feet and is 37 feet long. The top of the tank will be buried approximately 3 to 4 feet below existing grades. Therefore, the bottom of the tank will be about 13 to 14 feet below existing grades. Numerous HDPE and PVC inlet and outlet pipes are connected to the tank. If the proposed grades differ by more than 1 foot from the values indicated above, we should be informed. Additional analyses and recommendations will likely be necessary.

C.2. Discussion

Boring ST-1 was performed in the proposed tank area. The boring encountered 0.5 foot of organic clay underlain by slopewash to a depth of 6 1/2 feet, where decomposed claystone was encountered to 8 1/2 feet. Below 8 1/2 feet, high to very high plasticity claystone and shale bedrock was encountered to the boring's termination depth of 20 feet.

It is our opinion the high to very high plasticity claystone and shale 13 to 14 feet below existing grades on the site are highly expansive, i.e., will significantly shrink and swell with changes in moisture content. We anticipate several inches of settlement and heave could occur beneath the tank and connecting utility lines, which would generally be considered excessive. To reduce the amount of movement (not eliminate it), we recommend subexcavating 4 feet beneath the proposed tank bedding, then replacing these soils with non-expansive backfill. This 4 feet of non-expansive clay backfill will provide a "buffer" zone beneath the tank subgrade to reduce the risk of excessive shrinking and swelling.

C.3. Subexcavation and Replacement

To reduce the risk of excessive tank movement, we recommend subexcavating 4 feet below the proposed tank bedding material extending laterally 2 feet on either side of the tank bedding. This subexcavation and recommendations are indicated on attached Detail 1. As previously indicated, we anticipate high to very high plasticity claystone and shale bedrock will be encountered at this depth, and should be subexcavated a minimum of 4 feet below the bedding. The subexcavated claystone and shale should be replaced with non-expansive clay backfill, which most likely will have to be imported to the site.

Imported non-expansive clay backfill should have a plasticity index between 7 and 20, and have a minimum of 40 percent passing the 200 sieve. It should be placed at a moisture content no more than 1 percent below and up to 2 percent above optimum moisture content and compacted to a minimum of 98 percent of its standard Proctor maximum dry density. During placement, lift thicknesses should not exceed 8 inches uncompacted thickness, and full-time observations should be performed to confirm lift thicknesses, moisture content, and compaction are properly controlled during placement.

C.4. Anticipated Settlement and Heave

Even though 4 feet of non-expansive clay backfill is being provided beneath the tank, we anticipate up to 1 1/2 inches of total and differential movement could occur. We therefore recommend providing flexible connections for tank piping.

C.5. Impermeable Liner and Seepage Collection

As indicated on Detail 1, we recommend placing an impermeable liner on top of the non-expansive clay backfill, but beneath the pea gravel. The impermeable liner should wrap up the sides of the pea gravel placement approximately 2 feet. In the bottom of the pea gravel, we recommend providing a minimum of two high-strength perforated drainpipes to collect seepage. These drainpipes should have a minimum diameter of 4 inches and be routed to daylight or a sump/pump system.

C.6. Surface Backfill

On-site clays excavated to a depth of 8 1/2 feet primarily consisted of silty clay, lean clay, and sandy lean clay. It is our opinion these soils are suitable to be reused as backfill above the pea gravel bedding. We recommend they be brought all the way to the surface. Clay topsoil and seeding should also be provided at the surface rather than placing any washed rock, which could collect water and cause the soils to swell. We recommend the surface of the topsoil and clay slope down and away from the tank centerline at a minimum 3 percent slope to quickly drain surface water away from the tank excavation area.

We recommend the on-site clays be placed in lifts not exceeding 8 inches uncompacted thickness and at a moisture content within 2 percent of optimum moisture content. We recommend they be compacted to a minimum of 95 percent of their standard Proctor maximum dry density. Again, it is critical full-time observations of the placement, lift thicknesses, and compaction be performed for quality control.

D. Pump Building Analyses and Recommendations

D.1. Proposed Construction

The proposed pump building will be constructed approximately 50 feet down the slope from the buried water tank. The pump building is a pre-manufactured building with a concrete slab having plan dimensions of 12 feet by 14 feet. Provided details show this building as having several interior pressure tanks and piping that is suspended between the tanks, and extends beneath the floor. Boring ST-2 was performed in this area with a ground surface elevation of approximately 2276 1/2 based on the site contours. We have assumed the floor elevation will therefore be 2277 to 2278 based on this datum. If the floor elevation is incorrect, we should be informed. Additional analysis and recommendations will likely be necessary.

D.2. Discussion

Boring ST-2 encountered 0.7 foot of organic clay topsoil underlain by lean clay slopewash to a depth of 4 1/2 feet over medium to high plasticity shale bedrock to the boring's termination depth. Laboratory consolidation tests on the slopewash indicated it was highly collapsible, i.e., if it gets wet, it will consolidate. The underlying shale was found to be highly expansive. This is a very poor combination for an unheated building of this type and corrective earthwork beneath foundations will be needed to reduce the risk of excessive movement.

Our recommendations for the pump building are shown on Detail 2 attached to this report. We recommend supporting the proposed pump building on 5-foot deep frost-depth foundations around the perimeter. Beneath the perimeter footings, we recommend subexcavating the highly expansive shales to a depth of 4 feet, then replacing these soils with non-expansive clay backfill. It may be easier to remove all of these soils from beneath the entire building floor and proposed footings due to the relatively small size of the building. Because the building is unheated during the winter, it is our opinion a 4-inch void space or void form should be provided beneath the pre-cast concrete floor. These recommendations are described in more detail below.

D.3. Foundations

D.3.a. Depth. We recommend a minimum of 5 feet of earth cover over the bottoms of the exterior sides of perimeter footings for frost protection.

D.3.b. Subexcavation and Replacement. At a depth of 5 feet, we anticipate the highly expansive shales will be encountered. It is our opinion these soils are not suitable for direct footing support, and recommend subexcavating 4 feet below the footings, then replacing these soils with imported non-expansive clay backfill. Detail 2 for the pump building shows the subexcavation and replacement as well as the oversize zone needed beneath the proposed frost-depth footings.

Non-expansive clay backfill should have a plasticity index between 7 and 20 and not less than 40 percent passing the 200 sieve. The non-expansive clay backfill should be placed at a moisture content no less than 1 percent below and up to 2 percent above optimum moisture content, and in lifts not exceeding 8 inches uncompacted thickness. The non-expansive clay backfill should be compacted to a minimum of 95 percent of its standard Proctor maximum dry density. During placement, observations should be performed to confirm the lift sizes and moisture content meet these requirements, as well as compaction tests.

D.3.c. Bearing Pressure. It is our opinion footings may be designed for a net allowable bearing pressure up to 1,500 psf (fifteen hundred pounds per square foot). (Net allowable bearing pressure is defined as that bearing pressure in excess of the final minimum overburden pressure.) This bearing pressure includes a factor of safety of at least 3.0 against bearing capacity failure.

D.3.d. Anticipated Settlement and Heave. Even though providing 4 feet of non-expansive clay beneath the footings will act as a buffer zone, we still anticipate total and differential settlement and heave of foundations up to 1 1/2 inches could occur. If water were to infiltrate below the buffer zone, several inches of movement could occur. We therefore recommend providing flexible connections for piping entering and exiting the building. The structural engineer will need to evaluate if this amount of movement is acceptable. Another option is to support this small building on a deep foundation system, which does not appear warranted at this time.

D.3.e. Reinforcement. Sufficient reinforcing steel should be placed in the foundation walls to span isolated zones where foundation support could be lost due to localized settlement or heave of the soils or installation of subsurface utilities. This will also reduce the widths of cracks created by shrinkage of the concrete, and local settlement and heave of the soils. The amount of reinforcing should be determined by the project structural engineer.

D.3.f. Foundation Wall Backfill. We recommend backfill placed on the exterior sides of the foundation walls be compacted to a minimum of 95 percent of its standard Proctor maximum dry density. Soils from the footing excavations may be used. We recommend clay soils be placed at a moisture content within 2 percent of optimum moisture content. The levels of the exterior and interior backfills should not differ by more than 8 inches during placement or the walls should be braced, otherwise the foundation walls may be displaced.

E. Grease Interceptor and Pump Station Analyses and Recommendations

E.1. Proposed Construction

The grease interceptor and pump station are being constructed near the existing fish cleaning station, in the swale area located next to Hell Creek Road. The grease interceptor has plan dimensions of 5 feet by 9 feet and is a pre-cast concrete structure. This structure is buried approximately 7 feet below existing grades on the site and has manholes coming to the surface for cleanout. The proposed E-One pump station is planned to be a polyethylene-molded 486-gallon tank. (The lateral earth pressures described later may require a concrete tank.) This structure is typically placed on a concrete mat bearing approximately 8 to 9 feet below existing grades. The tank then extends up to the ground surface. Similarly, numerous inlet and outlet piping is also planned into this pump station.

E.2. Discussion

Unlike the other borings performed on the site, Boring ST-3 encountered wet, saturated clays to its termination depth of 20 feet. Even though these clays classified as fat clay and lean to fat clay, it is our opinion they are likely well above their optimum moisture content, and not likely to absorb additional moisture and swell. They key to these clays is therefore keeping them wet so they do not dry out and shrink. This is easily accomplished by using on-site soils as backfill and capping all of the soils with similar clay soils.

For these reasons, it is our opinion the grease interceptor and pump station tanks can be placed directly on the on-site clay soils encountered at the site. However, perched groundwater may be present and some dewatering could be necessary. Depending on the method of dewatering used by the contractor, there is a possibility the subgrade soils could become excessively disturbed during construction. A contingency in the project budget should be provided in case excessive disturbance occurs and working platforms are needed to be constructed beneath these structures.

We also recommend assuming groundwater at a depth of 3 feet. Higher lateral earth pressures occur for submerged conditions, and tanks need to be designed for buoyancy.

E.3. Depth

The two tanks are buried 7 feet or slightly more below existing grades, which in our opinion, is suitable for frost protection. Insulation panels may be needed for the tops of the tanks, as required by the manufacturer.

E.4. Subgrade

Boring ST-3 indicates the subgrade at the tank bottoms will typically be wet, saturated lean to fat clay. It is our opinion these soils are suitable for direct support of the proposed tanks and concrete foundations provided they are not excessively disturbed. We therefore recommend the excavations be performed with smooth-bladed buckets on the backhoes. Extreme care needs to be taken during excavation to avoid excessively disturbing these clays.

If perched groundwater is present, we recommend it be dewatered prior to continuing the excavation. The method of dewatering the area will need to be determined by the contractor based on their available equipment and experience.

If the subgrade is excessively disturbed, it may be necessary to construct a working platform to support these tanks. If that is necessary, we recommend subexcavating 1 foot below the tank bottom, placing an 8-ounce non-woven fabric along the subgrade and 1 foot up the sides, then placing 1 foot of 1-inch minus crushed base course. The crushed base course should be compacted using a vibratory plate compactor.

E.5. Bearing Pressure and Settlement and Heave

It is our opinion the net allowable bearing capacity of the underlying clays is 1,000 psf. We anticipate the total and differential settlement and heave of the tanks in this area will not exceed 1 inch. However, we recommend using flexible connections wherever possible to allow for shrinking and swelling to occur and not adversely affect the system.

E.6. Backfill

It is our opinion on-site soils should be used as backfill around the tanks. These clays, when reused and compacted, will be relatively impermeable, which is important to reduce the risk of drying out. We recommend the backfill be placed in lifts not exceeding 8 inches uncompacted thickness and at a moisture content within 2 percent of optimum moisture content. The on-site clays should be compacted to a minimum of 95 percent of their standard Proctor maximum dry density. On-site quality control and observations should be performed to confirm lift thicknesses, moisture content, and compaction.

E.7. Lateral Earth Pressures

The following lateral earth pressures should be used for design of below-grade concrete basins and pump stations. In the vicinity of the existing fish cleaning station, perched groundwater was observed at a depth of about 6 feet while drilling. We therefore recommend assuming groundwater levels as high as 3 feet on this site. Lateral earth pressures are much higher below groundwater than above groundwater, as the values in the below table indicate.

Table 3. Lateral Earth Pressure Parameters

Parameter	On-Site Clays Compacted Backfill
Moist Unit Weight, pcf	120
Saturated Unit Weight, pcf	125
Internal Angle of Friction, deg.	18
At-Rest Equivalent Fluid Pressure, psf/ft Above groundwater* Below groundwater*	 83 106
Passive Equivalent Fluid Pressure, psf/ft Above groundwater* Below groundwater*	 220 119
Coefficient of Friction	0.32

*Assume groundwater (possible perched groundwater) at a depth of 3 feet.

Note: The above values are not factored. Appropriate factors of safety are critical to prevent movement, cracking of concrete or tank materials, or failure.

E.8. Buoyancy

Tanks in this area need to be designed for buoyancy, unless the actual source for the groundwater is determined. As indicated above, we recommend assuming groundwater is at a depth of 3 feet.

F. Drainfield Area Tanks Analyses and Recommendations

F.1. Proposed Construction

As can be seen on the Drainfield Area Boring Location Sketch, two buried tanks are anticipated in the drainfield area including the 3,000-gallon recirculation tank and the similar size dose tank. These tanks will be pre-cast concrete structures having plan dimensions of approximately 7 feet by 15 feet and will be buried about 9 feet below existing grades on the site. Inlet and outlet pipes are needed for these tanks to connect them to the wastewater treatment system.

F.2. Discussion

Boring ST-4 was performed in the vicinity of these proposed tanks. The boring encountered 0.6 foot of organic clay topsoil underlain by lean clay decomposed claystone to 1 1/2 feet over silty sand decomposed sandstone to 6 feet. Decomposed claystone consisting of lean clay and sandy lean clay was then encountered to 11 feet where fat clay weathered claystone underlain by high plasticity claystone was encountered to the boring's termination depth of 20 feet. Groundwater was not encountered in the boring.

The fat clay encountered below a depth of 11 feet is highly expansive. We anticipate that if the tanks were placed directly on these subgrades, several inches of heave could occur, causing damage to the tanks and connecting piping. To reduce the risk of this movement, we recommend subexcavating 4 feet beneath the proposed tanks on a 2-foot oversize zone (lateral), then replacing these soils with non-expansive clay backfill.

F.3. Depth

The tanks will be buried 9 feet below existing grade, which in our opinion, is suitable for frost protection. Insulation panels may be needed at the top of the tank, as required by the manufacturer.

F.4. Subexcavation and Replacement

To reduce the risk of expansive soils, we recommend subexcavating the sandy lean clay then the underlying fat clay from beneath the proposed tanks to a depth of 4 feet. The subexcavation should extend laterally 2 feet beyond the tank edges. We then recommend replacing these soils with non-expansive clay backfill. Non-expansive clay backfill should have a plasticity index between 7 and 20 and not less than 40 percent passing the 200 sieve. The non-expansive clay backfill should be placed at a moisture content no less than 1 percent below and up to 2 percent above optimum moisture content, and in lifts not exceeding 8 inches uncompacted thickness. The non-expansive clay backfill should be compacted to a minimum of 95 percent of its standard Proctor maximum dry density. During placement, observations should be performed to confirm the lift sizes and moisture content meet these requirements, as well as compaction tests.

F.5. Bearing Pressure and Settlement and Heave

It is our opinion the net allowable bearing capacity of the underlying clays is 1,000 psf. We anticipate the total and differential settlement and heave of the tanks in this area will not exceed 1 1/2 inches. Again, we recommend using flexible connections wherever possible to allow for shrinking and swelling to occur and not adversely affect the system.

F.6. Backfill

We recommend using the on-site clays as backfill around the tanks. We wish to point out, however, the on-site silty sands should not be used because they could provide a conduit for water to reach the tank subgrades. The lean clays and fat clays from the 20,000-gallon tank area could also be used, if necessary.

We recommend the backfill around the tanks be placed in lifts, at a moisture content within 2 percent of optimum moisture content, and in uncompacted lifts not exceeding 8 inches. We recommend the backfill be compacted to a minimum of 95 percent of its standard Proctor maximum dry density. Again, lift thicknesses, moisture content, and compaction quality control should be performed during placement.

F.7. Lateral Earth Pressures

The following lateral earth pressures should be used for design of below-grade tanks. We do not anticipate groundwater will be present in the area.

Table 3. Lateral Earth Pressure Parameters

Parameter	On-Site Clays Compacted Backfill
Moist Unit Weight, pcf	120
Saturated Unit Weight, pcf	125
Internal Angle of Friction, deg.	18
At-Rest Equivalent Fluid Pressure, psf/ft	83
Passive Equivalent Fluid Pressure, psf/ft	220
Coefficient of Friction	0.32

*Assume groundwater (possible perched groundwater) at a depth of 3 feet.

Note: The above values are not factored. Appropriate factors of safety are critical to prevent movement, cracking of concrete or tank materials, or failure.

G. Water and Wastewater Pipeline Analyses and Recommendations

G.1. Materials

Laboratory corrosion tests on the clay soils encountered by the borings indicated they were highly corrosive to metallic conduits. We therefore recommend specifying non-corrosive materials for all pipelines on the project. It appears these pipelines are primarily HDPE and PVC, which meet these requirements. Pipelines using ductile iron pipe, aluminized steel, or steel should not be used for the project due to the high corrosion potential.

G.2. Utility Trench Bottoms and Bedding

The borings indicate primarily stiff to very stiff clay soils will be encountered at the utility trench bottoms although some layers of silty sand could also be present. In the vicinity of the existing fish cleaning station, some wet, saturated clays were found to be rather soft to medium consistent. Even so, we do not anticipate the need for Type 2 bedding along the project. We recommend the pipelines be installed in general accordance with *Montana Public Works Standard Specifications* (MPWSS), but recommend using well-graded sands and gravels as Type 1 bedding as described below.

MPWSS indicates Type 1 bedding can be 1 1/2-inch minus gravel with no requirement on the percent passing the 200 sieve (fines). Therefore, open-graded washed rock or drainage aggregate could be used as bedding. These gravels do not contain sand and fines, and therefore have significant voids between the gravels. Fluctuating groundwater associated with leaking utilities or lake flooding can transport fines into the voids, known as piping, resulting in settlement.

To reduce this risk, the open-graded bedding can be wrapped in filter fabric to reduce/prevent piping, but this is difficult to place during construction. Therefore, we recommend using well-graded sand and gravel as bedding, which reduces the risk of piping and settlement. This option is shown on MPWSS Standard Drawing No. 02221-2 as a pipe bedding alternative. We anticipate 1-inch or 3/4-inch minus crushed base course (MPWSS Section 02235) will meet these requirements, but submittals containing coefficient of uniformity (C_U) and curvature (C_C) should be submitted for approval.

G.3. Drainage and Impermeable Trench Plugs

It is critical good drainage of surface water be provided off of all buried pipelines. We recommend the final backfill at the surface be crowned to provide a minimum of a 3 percent cross slope. Even so, we recommend placing low permeable trench backfill plugs along the pipeline alignments. We recommend the plugs be placed in intervals of approximately 200 feet along every pipe. We also recommend plugs be placed along any service connections. These plugs should meet the requirements of MPWSS Section 02222.

G.4. Utility Backfill

After placement of bedding material, it is our opinion on-site soils can be used as trench backfill above bedding. To reduce trench settlement, it is critical the backfill be moistened to a moisture content within 2 percent of optimum, and placed in lifts not exceeding 8 inches thickness, and compacted to a minimum of 90 percent of its standard Proctor maximum dry density. Full-time observations should be performed to confirm proper lift sizes, moisture content, and compaction requirements are met. It is critical backfill adjacent to manholes, vaults, and valves be adequately compacted, or the risk of surface water infiltration is much higher. Hand-operated equipment is recommended for compaction in tight spaces.

H. Concrete

As the corrosion tests indicate, the on-site clays are considered very severely corrosive to concrete. Only two tests were performed, and one of the tests had a sulfate content of 2.39 percent. According to American Concrete Institute (ACI) requirements, Type V plus pozzolan cement is needed for concrete structures on the project.

I. Construction

I.1. Excavation

It is our opinion the soils encountered by the borings can be excavated with a backhoe. As previously indicated, the clay soils in the vicinity of the existing fish cleaning station where the new grease interceptor and pump station are being construction, should be excavated with a smooth-bladed bucket to avoid excessively disturbing the wet, saturated clays. We prefer this type of bucket for all excavations.

In the vicinity of the water tank, pump building, drainfield area tanks, and their associated utilities, it is our opinion the clay soils can be considered Type A soils and the silty sands considered Type C soils under Department of Labor Occupational Safety and Health Administration (OSHA) guidelines. In the grease interceptor and pump station area and utilities within 200 feet of these structures, it is our opinion the clay soils should be considered Type B to a depth of 6 feet, then Type C.

It is our opinion care needs to be taken during construction to avoid allowing the exposed clay subgrades from drying out. If they are allowed to dry out, they will shrink even further, then reabsorb moisture and swell. Care also needs to be taken for these fine-grained clays to avoid them from becoming wet during construction. It they become wet, they will become very soft and difficult to work on, which can cause delays and possible change orders.

I.2. Observations

We recommend the subgrades beneath the structures addressed in this report as well as pipelines be observed by a geotechnical engineer or an engineering technician working under the direction of a geotechnical engineer to see if the subgrade soils are similar to those encountered by the borings.

During excavations for footings and tanks, we recommend tests be conducted on the subgrades to evaluate if the bearing capacity is at least 1,000 or 1,500 psf. Typical instruments used for these tests include hand augers, penetrometers and sample tubes.

I.3. Moisture Conditioning

Numerous references have been made in the previous sections of this report regarding the moisture content of imported non-expansive clay backfill as well as on-site clay soils used as backfill. It is imperative these soils have a moisture content near or slightly above optimum moisture content during placement and compaction. This is a critical parameter to reduce the risk of heave as well as to achieve proper compaction. It will likely be necessary to add moisture to these clay soils in most areas of the project to achieve the moisture content requirements. The exception is in the vicinity of the existing fish cleaning station, where the clays are wet. It will likely be necessary to spread these clays out and allow them to dry during construction.

I.4. Testing

We recommend density testing of non-expansive clay backfill placed beneath tanks and footings to create the buffer zones as previously described in this report. Density tests should also be performed on backfill placed around these tanks and above utilities. These density tests are important to confirm the proper density has been achieved to reduce the risk of surface water infiltration reaching subgrades, causing movement. As previously indicated, compaction testing and observations should be performed full time in these areas to confirm the requirements are being met. We also recommend slump, air content and strength tests on Portland cement concrete.

I.5. Cold Weather Construction

If site grading and construction is anticipated during cold weather, we recommend good winter construction practices be observed. All snow and ice should be removed from cut and fill areas prior to additional grading. No fill should be placed on soils that have frozen or contain frozen material. No frozen soils should be used as fill.

Concrete delivered to the site should meet the temperature requirements of ASTM C 94. Concrete should not be placed on frozen soils or soils that contain frozen material. Concrete should be protected from freezing until the necessary strength is attained. Frost should not be permitted to penetrate below footings bearing on frost-susceptible soil since such freezing could heave and crack the footings and/or foundation walls.

If the earthwork and site preparation is planned during the winter and early spring, additional work will be required due to the inherent wetter ground conditions, increased rain or snow fall, frozen ground, lack of drying weather and shorter work days. This additional work often includes, but is not limited to, subexcavation of unsuitable material, imported suitable fill, geosynthetics, ground heaters, waste of frozen or wet material and higher testing and observation costs. The additional work can delay the contractor's schedule and result in substantial additional costs that are often passed onto the owner.

J. Procedures

J.1. Drilling and Sampling

The penetration test borings were performed on August 9 and 10, 2017, with a truck-mounted core and auger drill. Sampling for the borings was conducted in accordance with ASTM D 1586, "Penetration Test and Split-Barrel Sampling of Soils." Using this method, we advanced the borehole with hollow-stem auger to the desired test depth. Then a 140-pound hammer falling 30 inches drove a standard, 2-inch OD, split-barrel sampler a total penetration of 1 1/2 feet below the tip of the hollow-stem auger. The blows for the last foot of penetration were recorded and are an index of soil strength characteristics.

Several 3-inch diameter thin-walled tube samples were taken in clay soils in general accordance with ASTM D 1587, "Thin-walled Tube Sampling of Soils." The tubes were slowly pushed into undisturbed soils below the hollow-stem auger. After they were withdrawn from the boreholes, the ends of the tubes were sealed and the tubes were carefully transported to the laboratory.

J.2. Soil Classification

The drill crew chief visually and manually classified the soils encountered in the borings in accordance with ASTM D 2488, "Standard Practice for Description and Identification of Soils (Visual-Manual Procedures)." A summary of the ASTM classification system is attached. All samples were then returned to our laboratory for review of the field classifications by a geotechnical engineer. Representative samples will remain in our office for a period of 60 days to be available for your examination.

J.3. Groundwater Observations

About 10 minutes after taking the final sample in the bottom of a boring, the driller probed through the hollow-stem auger to check for the presence of groundwater. Immediately after withdrawal of the auger, the driller again probed the depth to water or cave-in. The boring was then backfilled. The depth to water or cave-in was noted, and the boring was then backfilled.

K. General Recommendations

K.1. Basis of Recommendations

The analyses and recommendations submitted in this report are based upon the data obtained from the soil borings performed at the locations indicated on the attached sketch. Often, variations occur between these borings, the nature and extent of which do not become evident until additional exploration or construction is conducted. A reevaluation of the recommendations in this report should be made after performing on-site observations during construction to note the characteristics of any variations. The variations may result in additional foundation costs, and it is suggested a contingency be provided for this purpose.

It is recommended we be retained to perform the observation and testing program for the site preparation phase of this project. This will allow correlation of the soil conditions encountered during construction to the soil borings, and will provide continuity of professional responsibility.

K.2. Review of Design

This report is based on the design of the proposed structure as related to us for preparation of this report. It is recommended we be retained to review the geotechnical aspects of the designs and specifications. With the review, we will evaluate whether any changes in design have affected the validity of the recommendations, and whether our recommendations have been correctly interpreted and implemented in the design and specifications.

K.3. Groundwater Fluctuations

We made water level observations in the borings at the times and under the conditions stated on the boring logs. These data were interpreted in the text of this report. The period of observation was relatively short, and fluctuation in the groundwater level may occur due to rainfall, flooding, irrigation, spring thaw, drainage, and other seasonal and annual factors not evident at the time the observations were made. Design drawings and specifications and construction planning should recognize the possibility of fluctuations.

K.4. Use of Report

This report is for the exclusive use of Great West Engineering, Inc., to use to design the proposed structure and prepare construction documents. In the absence of our written approval, we make no representation and assume no responsibility to other parties regarding this report. The data, analyses and recommendations may not be appropriate for other structures or purposes. We recommend parties contemplating other structures or purposes contact us.

K.5. Level of Care

Services performed by SK Geotechnical Corporation personnel for this project have been conducted with that level of care and skill ordinarily exercised by members of the profession currently practicing in this area under similar budget and time restraints. No warranty, expressed or implied, is made.

Professional Certification
I hereby certify that this report was prepared by me and that I am a duly Licensed Professional Engineer under the laws of the State of Montana.

Gregory T. Staffileno, PE
Principal, Geotechnical Engineer
License Number 10798PE
September 19, 2017

Appendix

MAP UNITS

Khc	Hell Creek Formation
Kfh	Fox Hills Formation
Qls	Landslide deposit

Structure contours in meters on top of the Judith River Formation

Contour interval: 20 meters (1 meter = 3.281 feet)
Datum: mean sea level

600 Structure contours on top of the Judith River Formation (Kjr) in meters

Montana Bureau of Mines and Geology
Open File No. 498

Geologic and Structure Contour Map of the Fort Peck Lake East 30' x 60' Quadrangle Eastern Montana

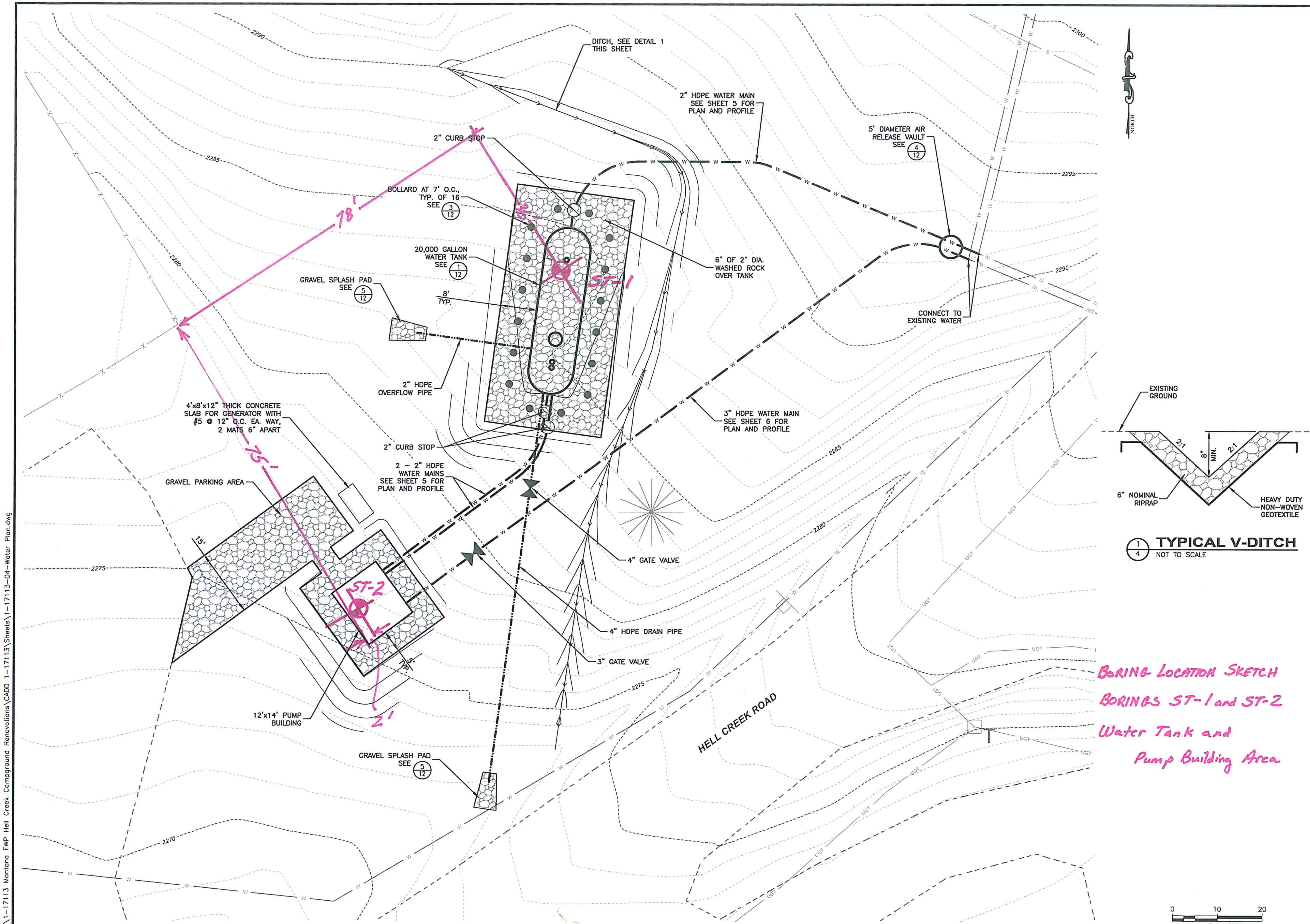
Edith M. Wilde and Robert N. Bergantino

2004

SK GEOTECHNICAL

GEOLOGIC SKETCH
Geotechnical Evaluation
Proposed Water Improvements
Hell Creek State Park
North of Jordan, Montana

Drawn by:	Google Earth/SKG	Date	8/16/17
Project:	17-3585G		
Scale:	NTS	FIGURE	
Sheet	1 of 1		



NO.	REVISION DESCRIPTION	BY	DATE

PROJECT: 1-17113
DESIGNED: TKK / BAA
DRAWN: BAA / TLC
CHECKED: —
APPROVED: TKK
DATE: AUGUST 11, 2017

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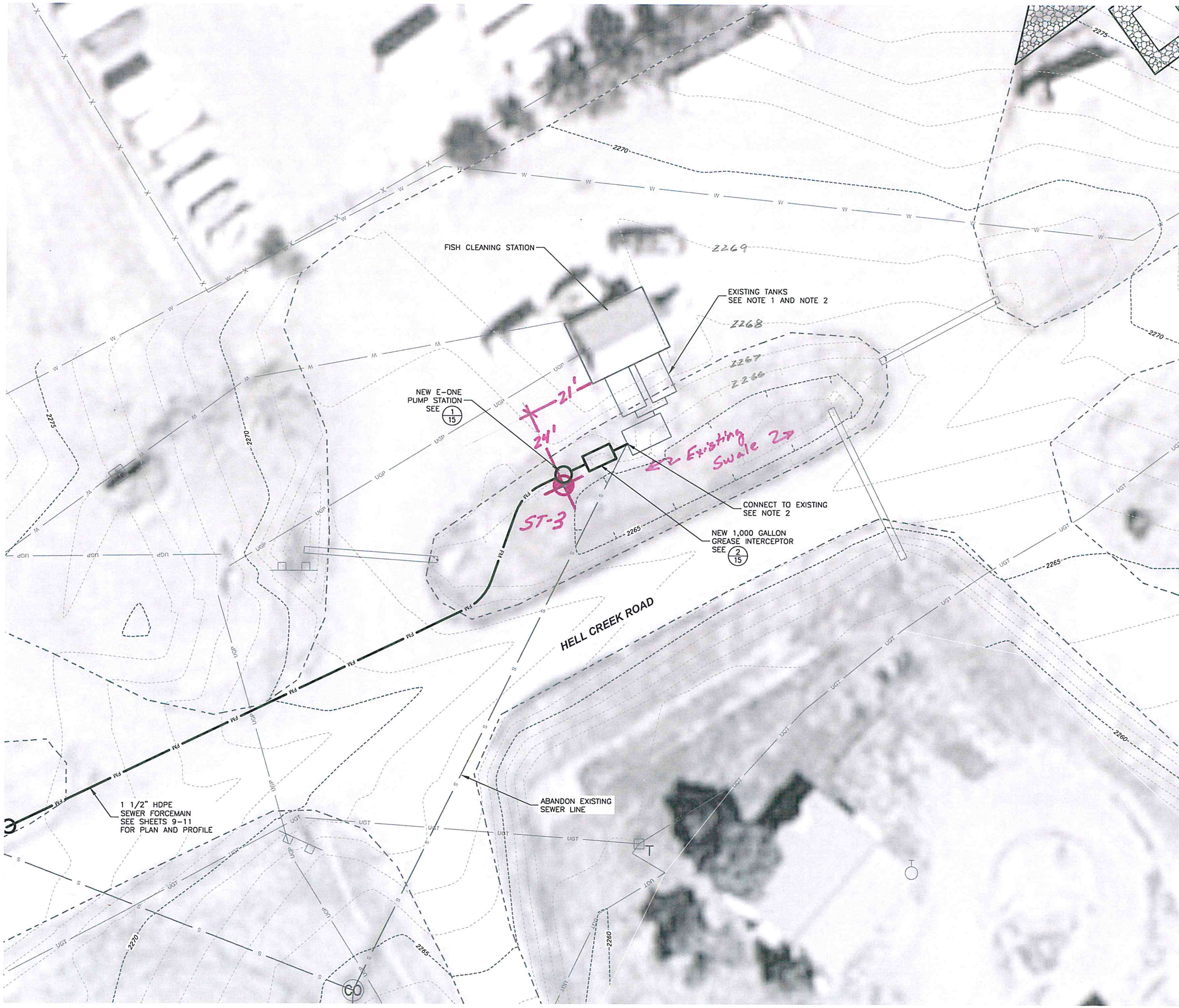
MONTANA FISH WILDLIFE & PARKS
HELL CREEK STATE PARK IMPROVEMENTS
WATER SYSTEM PLAN

SHEET NO.
4
OF 20



NORTH

BORING LOCATION SKETCH
BORING ST-3
Grease Interceptor and Pump Station Area

NOTES:
1. EMPTY EXISTING TANKS, REMOVE/DISPOSE OF EXISTING EFFLUENT FILTERS, AND INSTALL NEW EFFLUENT FILTERS. CONTRACTOR SHALL EMPTY TANKS AND MEASURE TO DETERMINE CORRECT EFFLUENT FILTER SIZES.
2. EXISTING TANK LOCATIONS ARE BASED ON BEST AVAILABLE INFORMATION. CONTRACTOR WILL VERIFY ORIENTATION AND LOCATION OF TANKS FOR CONNECTION OF GREASE TRAP.

0 15 30
SCALE IN FEET

NO.	REVISION DESCRIPTION	BY	DATE

PROJECT: 1-17113
DESIGNED: TKK / BAA
DRAWN: BAA / TLC
CHECKED: —
APPROVED: TKK
DATE: AUGUST 11, 2017

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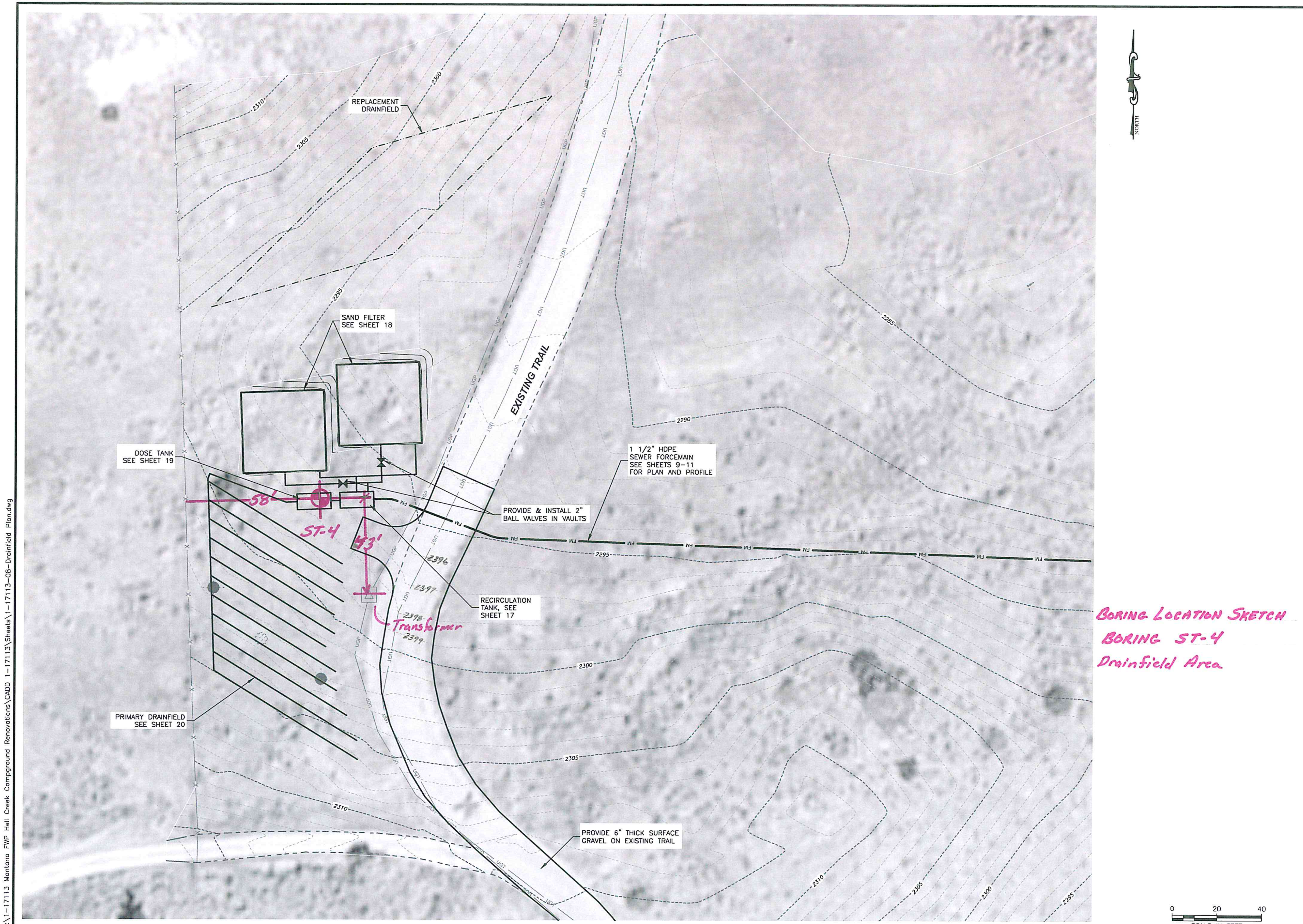
MONTANA FISH WILDLIFE & PARKS
HELL CREEK STATE PARK IMPROVEMENTS
FISH CLEANING STATION PLAN

SHEET NO.
7
OF 20

F:\1-17113 Montana FWP Hell Creek Campground Renovations\CADD 1-17113\Sheets\1-17113-07-Fish CS Plan.dwg



F:\1-17113 Montana FWP Hell Creek Campground Renovations\CADD 1-17113\Sheets\1-17113-08-Drainfield Plan.dwg

NO.	REVISION DESCRIPTION	BY	DATE
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PROJECT: 1-17113
DESIGNED: TKK / BAA
DRAWN: BAA / TLC
CHECKED: —
APPROVED: TKK
DATE: AUGUST 11, 2017

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MONTANA FISH WILDLIFE & PARKS
HELL CREEK STATE PARK IMPROVEMENTS

SAND FILTER AND DRAINFIELD PLAN

SHEET NO.
8
OF 20

Descriptive Terminology

Standard D 2487
Classification of Soils for Engineering Purposes
(Unified Soil Classification System)

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification: Group Symbol	Soil Classification: Group Name[B]
Coarse-Grained Soils More than 50% retained on No. 200 sieve	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines[C]	$C_U \geq 4$ and $1 \leq C_C \leq 3$[E]	GW	Well graded gravel[F]
			$C_U < 4$ and/or $1 > C_C > 3$[E]	GP	Poorly graded gravel[F]
		Gravels with Fines More than 12% fines[C]	Fines classify as ML or MH	GM	Silty gravel[F, G, H]
			Fines classify as CL or CH	GC	Clayey gravel[F, G, H]
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines[D]	$C_U \geq 6$ and $1 \leq C_C \leq 3$[E]	SW	Well graded sand[I]
			$C_U < 6$ and/or $1 > C_C > 3$[E]	SP	Poorly graded sand[I]
		Sands with Fines More than 12% fines[D]	Fines classify as ML or MH	SM	Silty sand[G, H, I]
			Fines classify as CL or CH	SC	Clayey sand[G, H, I]
Fine-Grained Soils 50% or more passes the No. 200 sieve	Silts and Clays Liquid Limit less than 50	Inorganic	PI > 7 and plots on or above "A" line[J]	CL	Lean clay[K, L, M]
			PI < 4 or plots below "A" line[J]	ML	Silt[K, L, M]
		Organic	$\frac{\text{Liquid limit – oven dried}}{\text{Liquid limit – not dried}} < 0.75$	OL	Organic clay[K, L, M, N] / Organic silt[K, L, M, O]
	Silts and Clays Liquid limit 50 or more	Inorganic	PI plots on or above "A" line	CH	Fat clay[K, L, M]
			PI plots below "A" line	MH	Elastic silt[K, L, M]
		Organic	$\frac{\text{Liquid limit – oven dried}}{\text{Liquid limit – not dried}} < 0.75$	OH	Organic clay[K, L, M, P] / Organic silt[K, L, M, Q]
Highly Organic Soils		Primarily organic matter, dark in color, and organic odor		PT	Peat

A Based on the material passing the 3" (75 mm) sieve.

B If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

C Gravels with 5 to 12% fines require dual symbols
- GW-GM well-graded gravel with silt
- GW-GC well-graded gravel with clay
- GP-GM poorly graded gravel with silt
- GP-GC poorly graded gravel with clay

D Sands with 5 to 12% fines require dual symbols.
- SW-SC well-graded sand with clay
- SP-SM poorly graded sand with silt
- SP-SC poorly graded sand with clay

E $C_U = D_{50} / D_{10}$

$C_C = (D_{30})^2 / (D_{10} \times D_{50})$

F If soil contains ≥ 15% sand, add "with sand" to group name.

G If fines classify as CL-ML, use dual symbol GC-GM or SC-SM.

H If fines are organic, add "with organic fines" to group name.

I If soil contains ≥ 15% gravel, add "with gravel" to group name.

J If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.

K If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel", whichever is predominant.

L If soil contains ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.

M If soil contains ≥ 30% plus No. 200 predominantly gravel, add "gravelly" to group name.

N PI ≥ 4 and plots on or above "A" line.

O PI < 4 or plots below "A" line.

P PI plots on or above "A" line.

Q PI plots below "A" line.

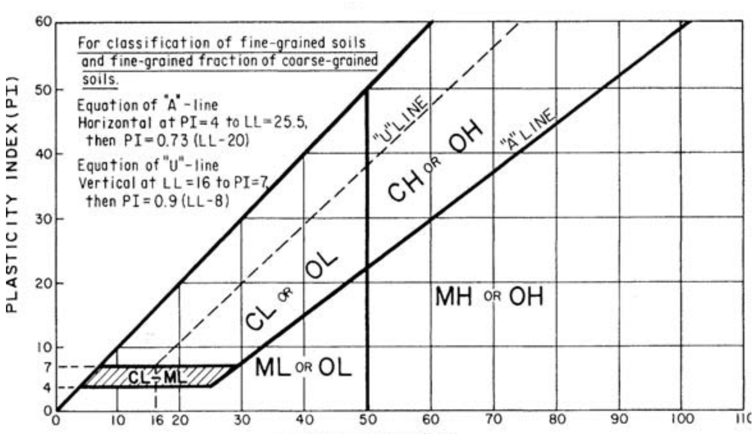

FIG. 4 Plasticity Chart

Laboratory Tests

DD	Dry density, pcf	OC	Organic content, %
WD	Wet density, pcf	P_{200}	% passing 200 sieve
LL	Liquid limit	PL	Plastic limit
PI	Plasticity index	MC	Natural moisture content, %
qu	Unconfined compressive strength, psf		
qp	Pocket penetrometer strength, tsf		

Particle Size Identification

Boulders	over 12"
Cobbles	3" to 12"
Gravel	
coarse	3/4" to 3"
fine	No. 4 to 3/4"
Sand	
coarse	No. 4 to No. 10
medium	No. 10 to No. 40
fine	No. 40 to No. 200
Silt	No. 200 to .005 mm
Clay	less than .005 mm

Relative Density of Cohesionless Soils

very loose	0 to 4 BPF
loose	5 to 10 BPF
medium dense	11 to 30 BPF
dense	31 to 50 BPF
very dense	over 50 BPF

Consistency of Cohesive Soils

very soft	0 to 1 BPF
soft	2 to 3 BPF
rather soft	4 to 5 BPF
medium	6 to 8 BPF
rather stiff	9 to 12 BPF
stiff	13 to 16 BPF
very stiff	17 to 30 BPF
hard	over 30 BPF

Moisture Content (MC) Description

rather dry	MC less than 5%, absence of moisture, dusty
moist	MC below optimum, but no visible water
wet	Soil is over optimum MC
waterbearing	Granular or low plasticity soil with free water, typically near or below groundwater table
very wet	Cohesive soil, typically near or below groundwater table

Drilling Notes

Standard penetration test borings were advanced by 3¼" or 4¼" ID hollow-stem augers, unless noted otherwise. Standard penetration test borings are designated by the prefix "ST" (split tube). Hand auger borings were advanced manually with a 2 to 3" diameter auger to the depths indicated. Hand auger borings are indicated by the prefix "HA."

Sampling. All samples were taken with the standard 2" OD split-tube sampler, except where noted. TW indicates thin-walled tube sample. CS indicates California tube sample.

BPF. Numbers indicate blows per foot recorded in standard penetration test, also known as "N" value. The sampler was set 6" into undisturbed soil below the hollow-stem auger. Driving resistances were then counted for second and third 6" increments and added to get BPF. Where they differed significantly, they were separated by backslash (/). In very dense/hard strata, the depth driven in 50 blows is indicated.

WH. WH indicates the sampler penetrated soil under weight of hammer and rods alone; driving not required.

Note. All tests were run in general accordance with applicable ASTM standards.

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LOG OF BORING

PROJECT: 17-3585G
GEOTECHNICAL EVALUATION
Proposed Water Improvements
Hell Creek State Park
North of Jordan, Montana

BORING: **ST-1**

LOCATION:
20,000-Gallon Water Tank, See Boring Location Sketch

DRILLED BY: C. Larsen | METHOD: 3 1/4" HSA, Automatic | DATE: 8/10/17 | SCALE: 1" = 3'

Elev.	Depth	Symbol	Description of Materials	BPF	WL MC	qp*	Remarks
2284.1	0.0						
2283.6	0.5	OL	ORGANIC CLAY with SAND and ROOTS, low plasticity, light olive brown, rather dry. (Topsoil)	6	7.2		Ground surface elevations estimated from contour lines on Site Plans.
2282.6	1.5	CL ML	SILTY CLAY, slightly plastic, trace sand and roots, light olive brown, rather dry, medium. (Slopewash)				
2277.6	6.5	CL	LEAN CLAY with SAND, low plasticity, trace roots, light olive brown, rather dry to moist, medium to rather soft. (Slopewash)	7 5	8.6 9.2		Flour-like appearance.
2275.6	8.5	CL	SANDY LEAN CLAY, low plasticity, olive brown, moist, medium. (Decomposed Claystone)	7	10.9		
2273.1	11.0		CLAYSTONE, olive brown to very dark gray, high plasticity, trace salts and FeOx, moist, very soft hardness.	17	19.8	4+	*qp=pocket penetrometer estimate of unconfined compressive strength, tons per square foot.
2263.6	20.5		SHALE, very dark gray, very high plasticity, trace FeOx and slickensides, fissiled, moist, very soft hardness.	21 TW 25 25	25.5 28.3 25.7 25.8		See swell test. LL=72, PL=22, PI=50 P_{200}=98%
			END OF BORING Water not observed with 19' of hollow-stem auger in the ground. Water not observed to dry cave-in depth of 6.4' immediately after withdrawal of auger.				

BORING BPF WL-MC QP* 3585.GPJ LAGNNN06.GDT 9/18/17

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LOG OF BORING

PROJECT: 17-3585G **GEOTECHNICAL EVALUATION** Proposed Water Improvements Hell Creek State Park North of Jordan, Montana	BORING: **ST-2** LOCATION: Pump Building, See Boring Location Sketch

DRILLED BY: C. Larsen	METHOD: 3 1/4" HSA, Automatic	DATE: 8/10/17	SCALE: 1" = 3'

Elev. 2276.6	Depth 0.0	Symbol	Description of Materials	BPF	WL MC	qp	Remarks
2275.9	0.7	OL	ORGANIC CLAY, low plasticity, some roots, light brown, rather dry. (Topsoil)				
		CL	LEAN CLAY, medium plasticity, trace pinholes and roots, light olive brown, rather dry, medium. (Slopewash)	8	6.1		Bag sample 1'-5' LL=48, PL=17, PI=31 P_{200}=93% MDD=104.0 pcf OMC=19.4%
				7	11.1		
2272.1	4.5			TW	11.4		See consolidation test. LL=44, PL=14, PI=30 P_{200}=95%
2270.1	6.5		SHALE, dark olive brown, moist, medium to high plasticity, sandy, trace salts, very soft hardness.	15	15.0		
			SHALE, very dark gray, moist, high plasticity, trace salts, FeOx, layers of sand, very soft hardness.	21	21.0		
			-gray sandstone boulder at 9.5' -trace schist and thin sandy layers with FeOx staining below 10'	21/7	15.8		
				23	21.5		
				5/12	22.9		
2256.1	20.5			29	23.2		
			END OF BORING Water not observed with 19' of hollow-stem auger in the ground. Water not observed to dry cave-in depth of 7' immediately after withdrawal of auger.				

BORING BPF WL-MC QP 3585.GPJ LAGNNN06.GDT 9/18/17

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LOG OF BORING

PROJECT: 17-3585G **GEOTECHNICAL EVALUATION** Proposed Water Improvements Hell Creek State Park North of Jordan, Montana	BORING: **ST-3** LOCATION: Grease Interceptor, See Boring Location Sketch

DRILLED BY: C. Larsen	METHOD: 3 1/4" HSA, Automatic	DATE: 8/9/17	SCALE: 1" = 3'

Elev. 2265.8	Depth 0.0	Symbol	Description of Materials	BPF	WL MC	qp	Remarks
2265.0	0.8	OL	ORGANIC CLAY with ROOTS, low to medium plasticity, olive brown, rather dry. (Topsoil)				
		CH	FAT CLAY, high plasticity, trace roots, dark olive brown, moist, medium to rather soft. (Decomposed Claystone)	8	19.7		
				5	22.8	4+	
2262.3	3.5	CL CH	LEAN to FAT CLAY, medium to high plasticity, trace roots, dark olive brown, moist to wet, medium to rather soft. (Decomposed Claystone)	7	21.6	2¼	Possible perched groundwater at about 6', as indicated by wet clays.
			-sandstone gravels at 7½'	5	31.7	¾	
				TW			
				7	28.1	1	
			-sandstone gravels, schist, light brown clays below 12½'	5	26.5	1½	
				5	29.3	1	
			-saturated clays below 19½', waterbearing	4	∇ 30.9	½	
2245.3	20.5		END OF BORING Water not observed with 19' of hollow-stem auger in the ground. Water not observed to dry cave-in depth of 3' immediately after withdrawal of auger.				

BORING BPF WL-MC QP 3585.GPJ LAGNNN06.GDT 9/18/17

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LOG OF BORING

PROJECT: 17-3585G
GEOTECHNICAL EVALUATION
Proposed Water Improvements
Hell Creek State Park
North of Jordan, Montana

BORING: **ST-4**

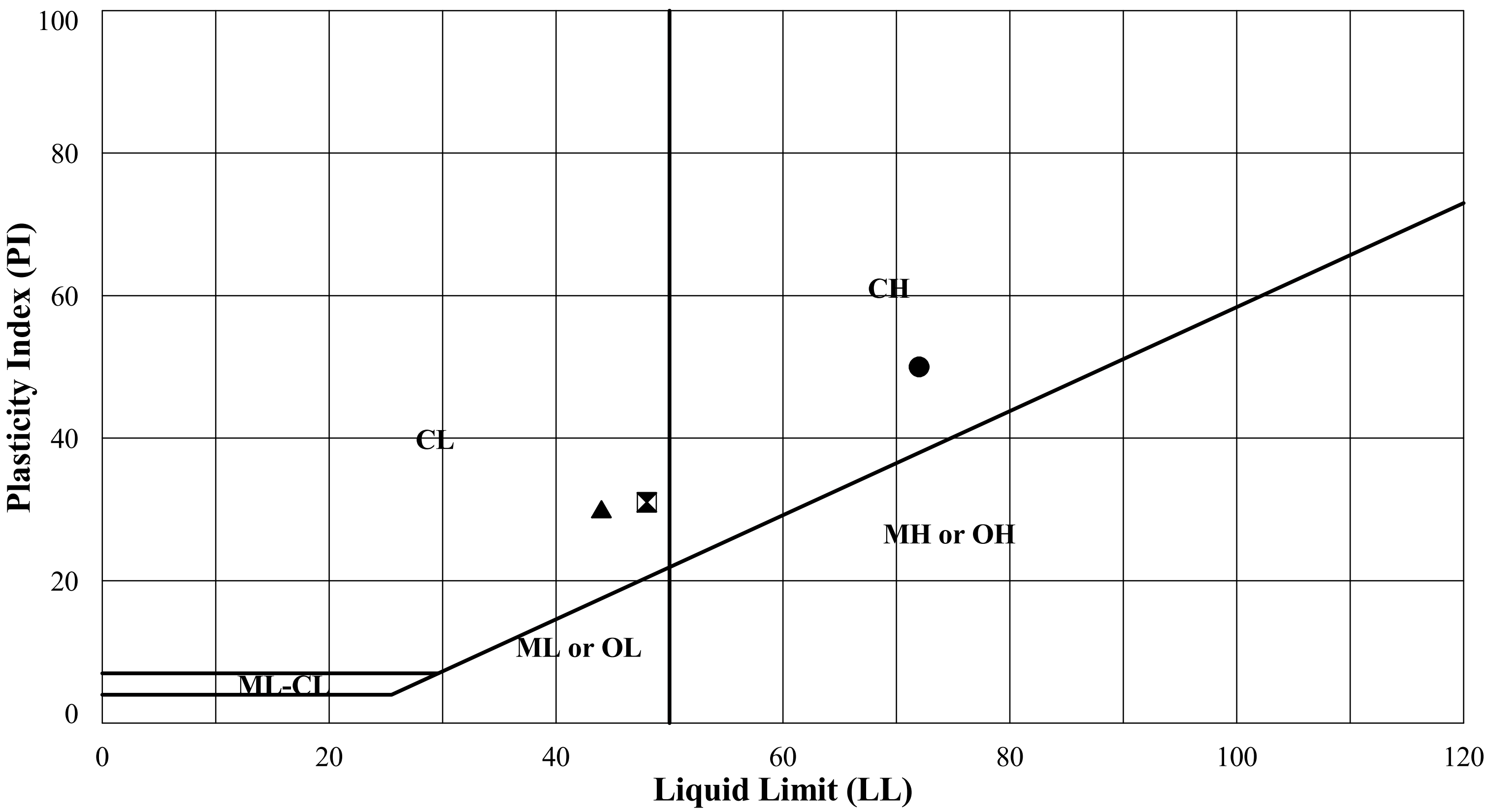
LOCATION:
Drainfield Area, See Boring Location Sketch

DRILLED BY: C. Larsen | METHOD: 3 1/4" HSA, Automatic | DATE: 8/9/17 | SCALE: 1" = 3'

Elev. 2396.4	Depth 0.0	Symbol	Description of Materials	BPF	WL MC	qp	Remarks
2395.8	0.6	OL	ORGANIC CLAY with ROOTS, low to medium plasticity, olive brown, rather dry. (Topsoil)				See Boring Location Sketch for benchmark.
2394.9	1.5	CL	LEAN CLAY with SAND, low plasticity, trace roots, light olive brown, rather dry, medium. (Decomposed Claystone)	8	6.9		
2390.4	6.0	SM	SILTY SAND, fine-grained, trace lenses of lean clay, light olive brown, rather dry, medium dense. (Decomposed Sandstone)	11	4.7		Bag Sample 1'-5'
				11	3.5		
2387.9	8.5	CL	LEAN CLAY, medium plasticity, some salts, trace sand, olive brown, moist, stiff. (Decomposed Claystone)	16	14.9		
				TW			
2385.4	11.0	CL	SANDY LEAN CLAY, low to medium plasticity, trace salts and lenses of silty sand, olive brown, moist, stiff. (Decomposed Claystone)	15	7.5		
2382.9	13.5	CH	FAT CLAY, high plasticity, trace salts, dark olive brown, moist, stiff. (Weathered Claystone)	16	17.6	4+	
2375.9	20.5		CLAYSTONE, dark olive ray, high plasticity, trace salts, very soft hardness.	26	16.5	4+	
				30	20.0	4+	

END OF BORING
Water not observed with 19' of hollow-stem auger in the ground.
Water not observed to dry cave-in depth of 7.6' immediately after withdrawal of auger.

BORING BPF WL-MC QP 3585.GPJ LAGNNN06.GDT 9/18/17



Legend	Boring	Sample No.	Depth	LL	PL	PI	P 200	MC	Classification
●	ST-1	TW	13' to 14'	72	22	50	98%	28.3%	CH
⧗	ST-2	P-1	1' to 5'	48	17	31	93%	6.9%	CL
▲	ST-2	TW	3' to 4'	44	14	30	95%	11.4%	CL

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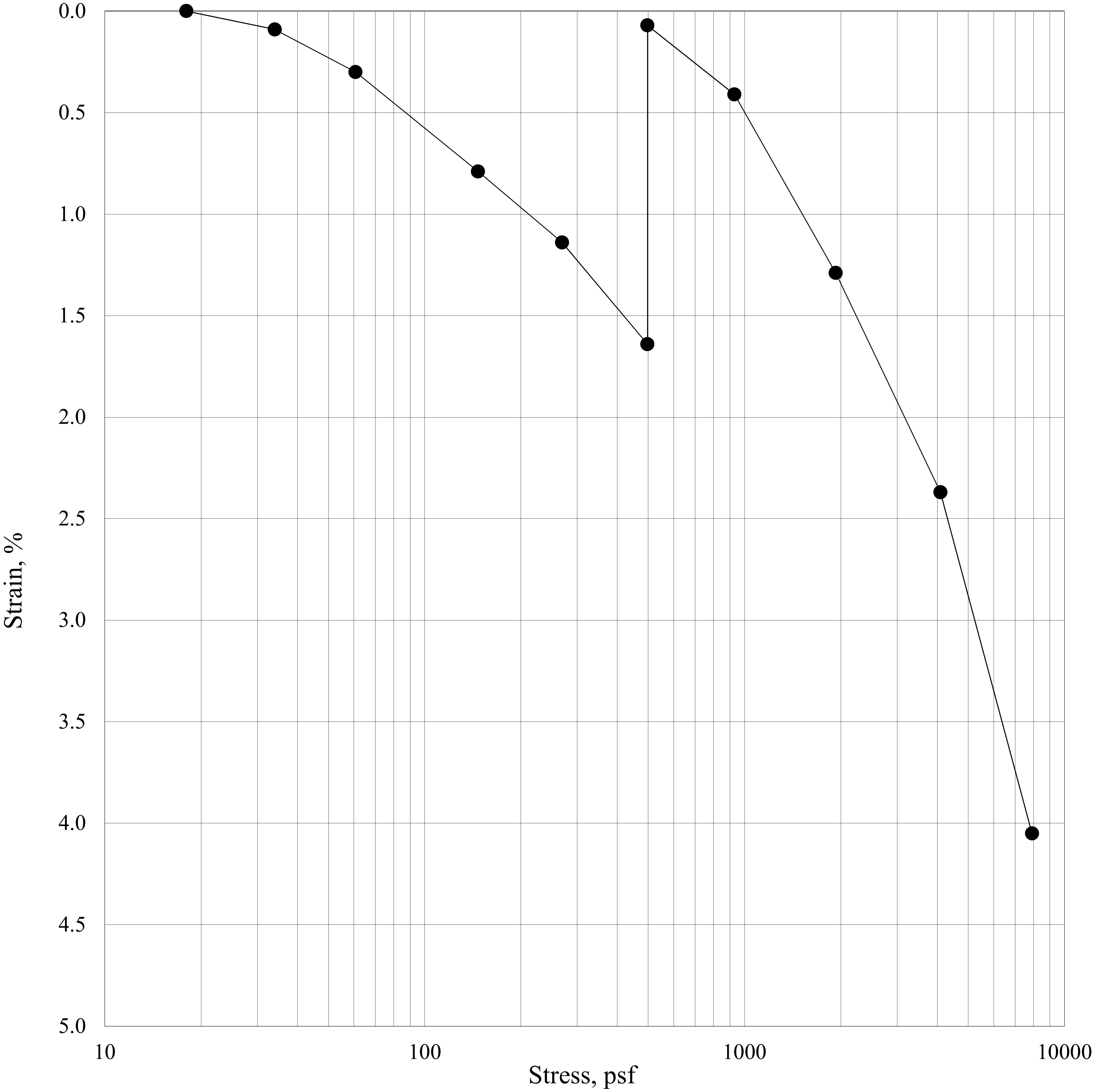
Atterberg Limits Tests

Project Number: 17-3585G
Proposed Water Improvements
Hell Creek State Park

9/19/17



				Initial Dry Density (pcf)	Initial Moisture Content (%)
Boring No.	ST-1	Depth:	13 - 14 '	**93.6**	**28.3**
Sampled By:	Drill Crew	Date Received:	8/15/17		

Soil Description: SHALE (Soil Class: Fat Clay (CH), high plasticity, trace slickensides, schist, olive brown, moist.

9/18/17

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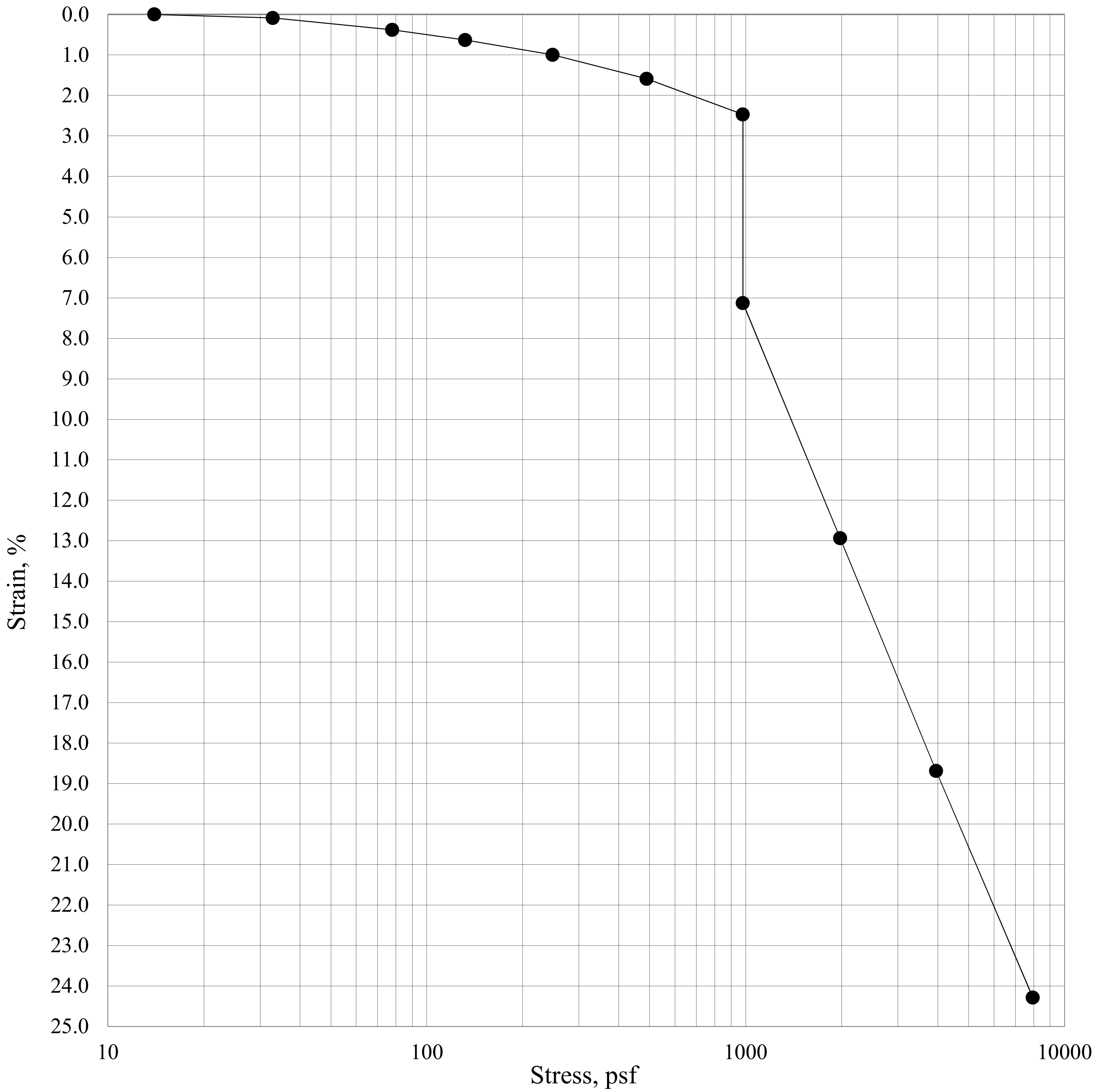
Consolidation/Swell Test

Project Number: 17-3585G
Hell Creek Park Improvement
Jordan, Montana



				Initial Dry Density (pcf)	Initial Moisture Content (%)
Boring No.	ST-2	Depth:	3.0'-4.0'	**81.1**	**11.4**
Sampled By:	Drill Crew	Date Received:	8/14/17		

Soil Description: Lean Clay (CL), medium plasticty, trace salts, roots, pinholes, light olive brown, moist.

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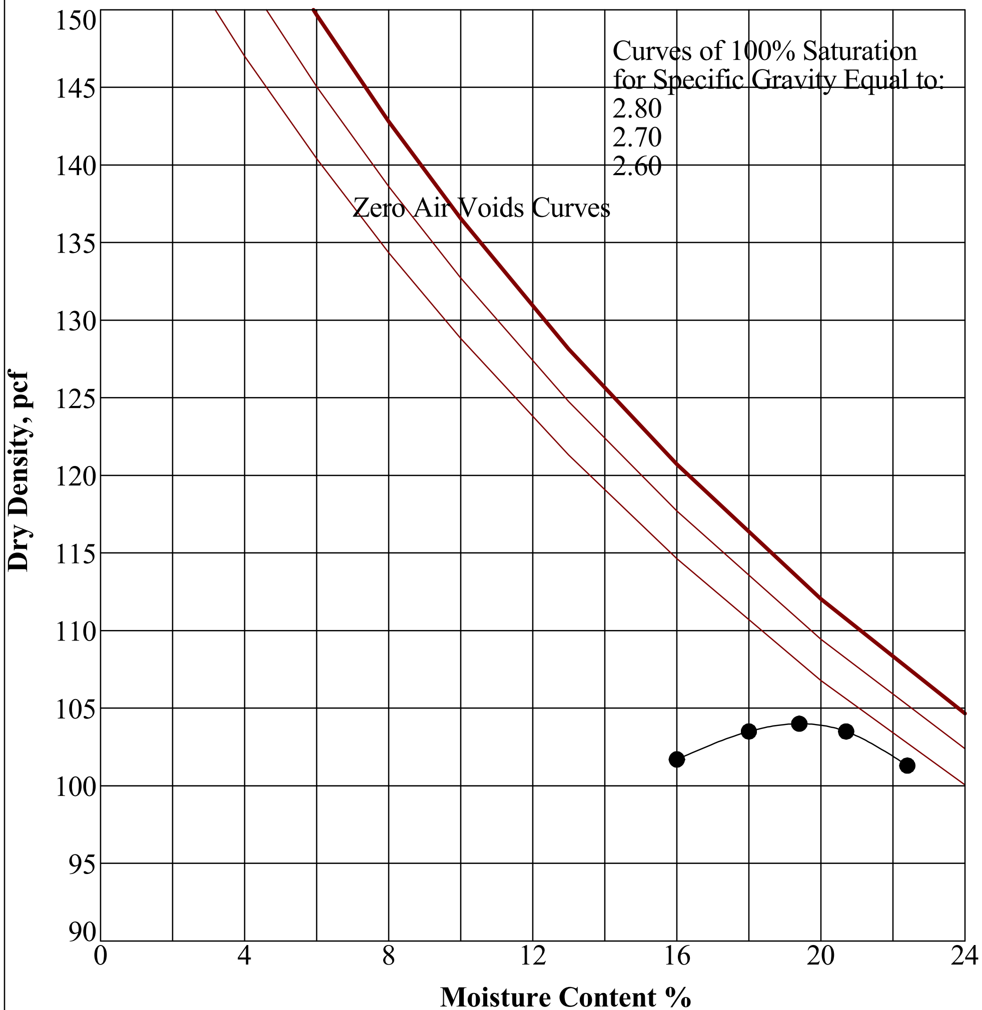
Consolidation/Swell Test

Project Number: 17-3585G
Hell Creek Park Improvement
Jordan, Montana



ASTM D 698 Method A

Maximum Dry Density, pcf	Optimum Moisture Content %
104.0	**19.4**

Rammer Type: Mechanical
Preparation Method: Moist

Soil Description (Visual-Manual)

Lean Clay [CL]

Sieve Size	% Retained
1 1/2"	0
3/4"	0
3/8"	0
#4	0

Sample No:	Bag Sample
Lab Sample No:	P-1
Date Sampled:	08/10/2017
Sampled By:	Drill Crew
Date Received:	08/16/2017
Sampled From:	ST-2
Depth:	1' to 5'
Performed by:	RJQ/SKG
Date Performed:	08/17/2017

Comments

Remarks

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Laboratory Compaction Characteristics of Soil (Proctor)

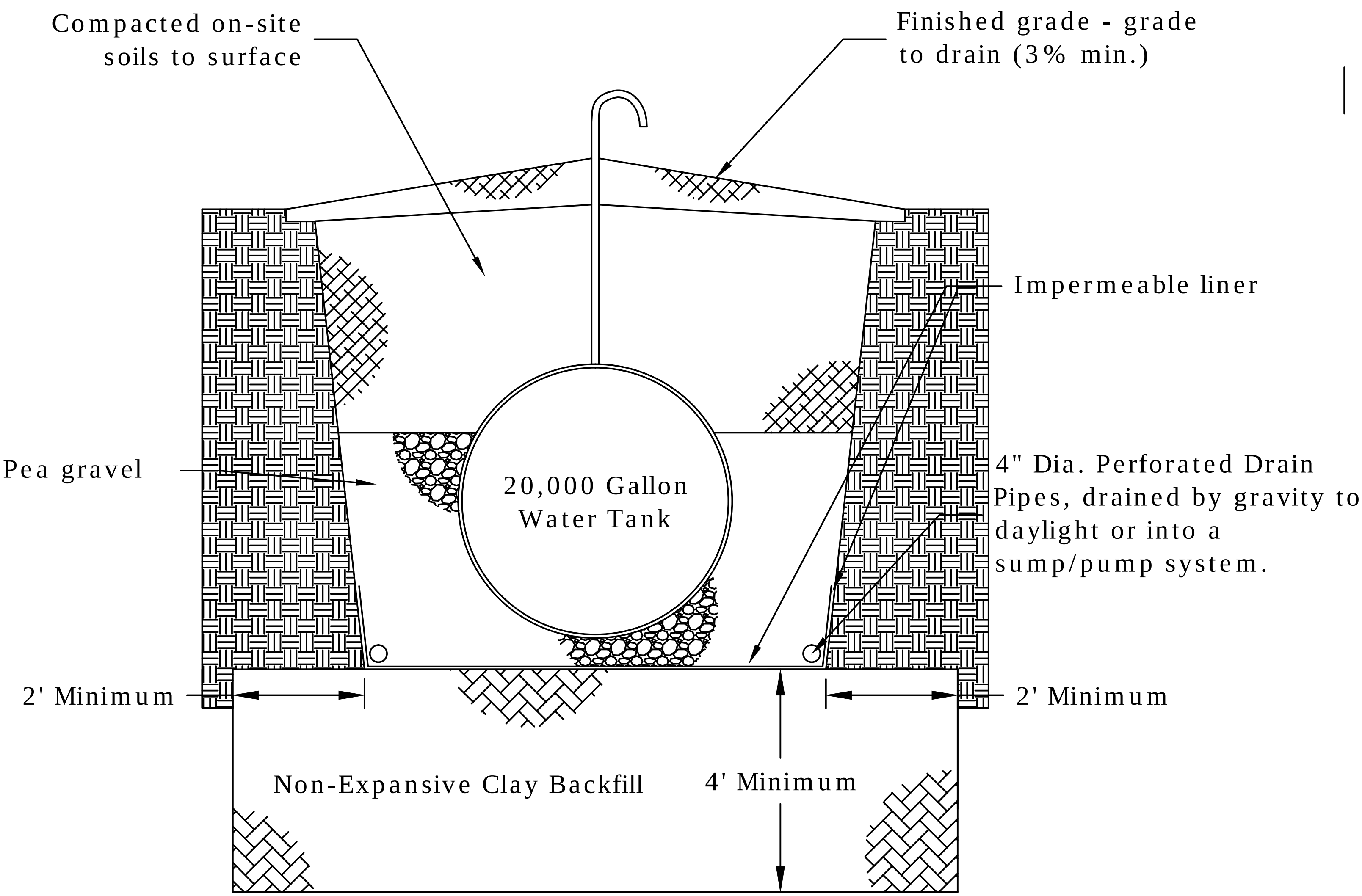
Project No.: 17-3585G
Proposed Water Improvements
Hell Creek State Park

PROCTOR

P-1

9/19/17

Detail 1. Water Tank



Detail 2. Pump Building